PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04N 7/26, 7/50

A1

(11) International Publication Number: **WO 98/44739**

(43) International Publication Date: 8 October 1998 (08.10.98)

(21) International Application Number: PCT/IB98/00732

(22) International Filing Date: 31 March 1998 (31.03.98)

(30) Priority Data:

60/041,777	31 March 1997 (31.03.97)	US
09/052,870	31 March 1998 (31.03.98)	US

(81) Designated States: JP, KR, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

With international search report.

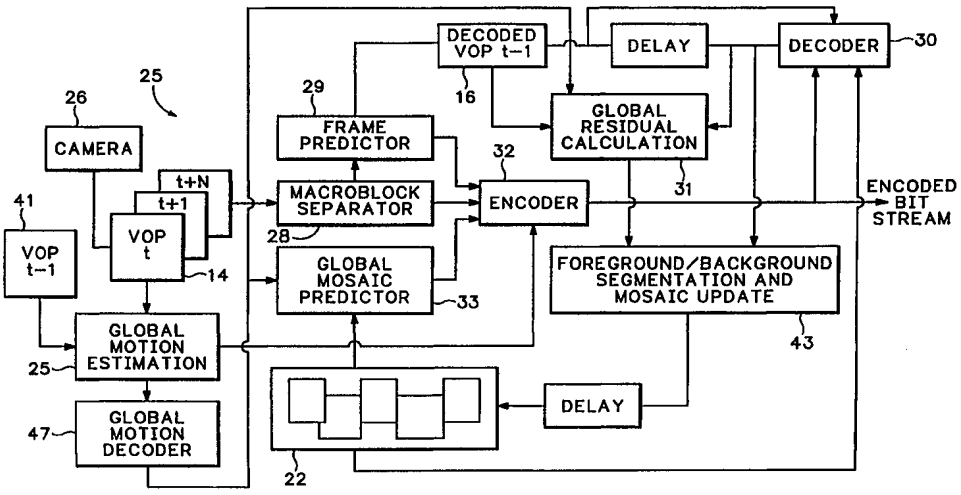
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(71) Applicant: SHARP KABUSHIKI KAISHA [JP/JP]; 22–22, Nagaike–cho, Abeno–ku, Osaka–shi, Osaka 545–0013 (JP).

(72) Inventors: CRINON, Regis, J.; 2346 N.W. Cascade Street, Camas, WA 98607 (US). SEZAN, Muhammed, Ibrahim; 2213 N.W. Hood Drive, Camas, WA 98607 (US).

(74) Agent: TAKANO, Akichika; Nagisa Patent Office, Salute Building, 9th floor, 72, Yoshida–cho, Naka–ku, Yokohama–shi, Kanagawa 231–0041 (JP).

(54) Title: MOSAIC GENERATION AND SPRITE–BASED IMAGE CODING WITH AUTOMATIC FOREGROUND AND BACKGROUND SEPARATION



(57) Abstract

An automatic segmentation system distinguishes foreground and background objects by first encoding and decoding a first image at a first time reference. Macroblocks are extracted from a second image at a second time reference. The macroblocks are mapped to pixel arrays in the decoded first image. Frame residuals are derived that represent the difference between the macroblocks and the corresponding pixel arrays in the previously decoded image. A global vector representing camera motion between the first and second images is applied to the macroblocks in the second image. The global vectors map the macroblocks to a second pixel array in the first decoded image. Global residuals between the macroblocks and the second mapped image arrays in the first image are derived. The global residuals are compared with the frame residuals to determine which macroblocks are classified as background and foreground. The macroblocks classified as foreground are then blended into a mosaic.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

MOSAIC GENERATION AND SPRITE-BASED IMAGE CODING WITH AUTOMATIC FOREGROUND AND BACKGROUND SEPARATION

BACKGROUND OF THE INVENTION

This invention relates to mosaic generation and sprite-based coding, and more particularly, to sprite-based coding with automatic foreground and background segmentation. Throughout the document, the terms "sprite" and "mosaic" will be used interchangeably.

Dynamic sprite-based coding can use object shape information to distinguish objects moving with respect to the dominant motion in the image from the rest of the objects in the image. Object segmentation may or may not be available before the video is encoded. Results of sprite-based coding with apriori object segmentation increases coding efficiency at sufficiently high bit rates where segmentation information, via shape coding, can be transmitted.

When object segmentation is available and transmitted, sprite reconstruction uses the dominant motion of an object (typically, a background object) in every video frame to initialize and update the content of the sprite in the encoder and decoder. Coding efficiency improvements come from scene re-visitation, uncovering of background, and global motion estimation. Coding gains also come from smaller transmitted residuals as global motion parameters offer better prediction than local motion vectors in background areas. Less data is transmitted when a scene in revisited or background is uncovered because the uncovered object texture has already been observed and has already been incorporated into the mosaic sometime in the past. The encoder selects the mosaic content to predict uncovered background regions or other re-visited areas. Coding gains come from the bits saved in not having to transmit local motion vectors for sprite predicted macroblocks.

However, the segmentation information may not be available beforehand. Even when available, it may not be possible to transmit segmentation information when the

communication channel operates at low bit rates. Shape information is frequently not available since only a small amount of video material is produced with blue screen overlay modes. In these situations, it is not possible to distinguish among the various objects in each video frame. Reconstruction of a sprite from a sequence of frames made of several video objects becomes less meaningful when each object in the sequence exhibits distinct motion dynamics. However, it is desirable to use dynamic sprite-based coding to take advantage of the coding efficiency at high bit rates and if possible, extend its performance at low bit rates as well. Shape information takes a relatively larger portion of the bandwidth at low bit rate. Thus, automatic segmentation provides a relatively larger improvement in coding efficiency at low bit rates.

Current sprite-based coding in MPEG-4 assumes that object segmentation is provided. With the help of segmentation maps, foreground objects are excluded from the process of building a background panoramic image. However, the disadvantage of this approach is that object segmentation must be performed beforehand. Object segmentation is a complex task and typically requires both spatial and temporal processing of the video to get reliable results.

Temporal linear or non-linear filtering is described in U.S. Patent No. 5,109,435, issued April 28, 1992, entitled Segmentation Method for Use Against Moving Objects to Lo, et al. Temporal filtering is used for segmenting foreground objects from background objects for the purpose of reconstructing image mosaics. This approach has two disadvantages: First, it requires that several frames be pre-acquired and stored so temporal filtering can be performed. Second, it does not explicitly produce a segmentation map, which can be used to refine motion estimates.

Analysis of motion residuals is described in U.S. Patent No. 5,649,032, issued July 15, 1997, entitled System for Automatically Aligning Images to Form a Mosaic Image, to Burt, et al. This method separates foreground objects from background objects in a mosaic but does not reconstruct a mosaic representative of the background object only (see

description in the Real time transmission section). Post-processing must be used to eliminate the foreground objects.

Accordingly, a need remains for automatically performing on-line segmentation and sprite building of a background image (object undergoing dominant motion) when prior segmentation information is neither available nor used due to bandwidth limitations.

SUMMARY OF THE INVENTION

Automatic object segmentation generates high quality mosaic (panoramic) images and operates with the assumption that each of the objects present in the video scene exhibits dynamical modes which are distinct from the global motion induced by the camera. Image segmentation, generation of a background mosaic and coding are all intricately linked. Image segmentation is progressively achieved in time and based on the quality of prediction signal produced by the background mosaic. Consequently, object segmentation is embedded in the coder/decoder (codec) as opposed to being a separate pre or post-processing module, reducing the overall complexity and memory requirements of the system.

In the encoder, foreground and background objects are segmented by first encoding and decoding a first image at a first time reference. The method used to encode and decode this first image does not need to be specified for the purpose of this invention. The second image at a second time reference is divided into non-overlapping macroblocks (tiles). The macroblocks are matched to image sample arrays in the decoded first image or in the mosaic. In the first case, the encoder uses local motion vectors to align an individual macroblock with one or several corresponding image sample array in the previous decoded image. In the second case, the encoder uses parameters of a global motion model to align an individual macroblock with a corresponding mosaic sample array. The encoder evaluates the various residuals and selects the proper prediction signal to use according to a pre-specified policy. This decision is captured in the macroblock type. The macroblock types, the global motion parameters, the local motion vectors and the residual signals are transmitted to the decoder.

Frame residuals represent the difference between the macroblocks and corresponding image arrays in the previously decoded image matched by using local motion vectors. Macroblocks having a single local motion vector are identified as INTER1V-type macroblocks. Macroblocks having multiple (4) local motion vectors are identified as INTER4V-type macroblocks. INTER4V macroblocks are always labeled as foreground. INTER1V macroblocks can either be labeled foreground or background.

A global motion model representing camera motion between the first and second image is applied to the macroblocks in the second image. The global vector maps the macroblocks to a corresponding second image sample array in the first decoded image. Global residuals between the macroblocks and the second image array are derived. When the global residuals are greater than the INTER1V frame residuals, the macroblocks are classified as foreground. When the INTER1V frame residuals are greater than the global residuals, the macroblocks are classified as background. By comparing the global residuals to the INTER1V frame residuals derived from the previously decoded image the mosaic can be automatically updated with the image content of macroblocks likely to be background.

Mosaic residuals represent the difference between the macroblocks and corresponding global motion compensated mosaic arrays. Any macroblocks tagged as mosaic prediction type are classified as background.

A segmentation map can be used to classify the macroblocks as either foreground or background. A smoothing process is applied to the segmentation map to make foreground and background regions more homogeneous. The mosaic is then updated with the contents of macroblocks identified as background in the smoothed segmentation map.

Automatic segmentation does not require any additional frame storage and works in a coding and in a non-coding environment. In a non-coding environment, the invention operates as an automatic segmentation-based mosaic image reconstruction encoder. Automatic object segmentation builds a mosaic for an object exhibiting the most dominant motion in the video sequence by isolating the object from the others in the video sequence and reconstructing a sprite for that object only. The sprite becomes more useable since it is

related to only one object. The results of the auto-segmentation can be used to obtain more accurate estimates of the dominant motion and prevent the motion of other objects in the video sequence from interfering with the dominant motion estimation process.

Automatic object segmentation can be integrated into any block-based codec, in particular, into MPEG4 and is based on macroblock types and motion compensated residuals. Dominant motion compensation is used with respect to the most recently decoded VO plane. A spatial coherency constraint is enforced to maintain the uniformity of segmentation. Automatic segmentation is used in a non-coding environment, for example in the context of building a background image mosaic only (or region undergoing dominant motion) in the existence of foreground objects. Thus, automatic sprite-based segmentation is not only useful for on-line dynamic sprites but can also be used in generating an off-line (e.g., background) sprite that can be subsequently used in static sprite coding.

The foregoing and other objects, features and advantages of the invention will become more readily apparent from the following detailed description of a preferred embodiment of the invention, which proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of an image frame divided into multiple macroblocks.

FIG. 2 is a diagram showing an INTER1V prediction mode.

FIG. 3 is a diagram showing an INTER4V prediction mode.

FIG. 4 is a diagram showing a MOSAIC prediction mode.

FIG. 5 is a block diagram of an automatic segmentation encoder and decoder according to the invention.

FIG. 6 is a step diagram showing how the automatic segmentation is performed according to the invention.

FIG. 7 is a step diagram showing how macroblocks in the image frame shown in FIG. 1 are classified as foreground and background according to the invention.

FIG. 8 is a schematic representation showing how the macroblocks are classified as foreground and background.

FIG. 9 is a segmentation map and smoothed segmentation map according to another feature of the invention.

FIG. 10 is a step diagram showing how pixels in background macroblocks are blended into a mosaic.

FIG. 11 is a table showing results of the automatic segmentation according to the invention.

DETAILED DESCRIPTION

Referring to FIG. 1, automatic segmentation extracts a background object 13, such as a hillside or a tree, from a sequence of rectangular-shaped video object planes (VOPs) 18. The VOPs 18 are alternatively referred to as frames or image frames. It is assumed that a previous decoded VOP 16 is available at time t-1. A current VOP 14 is available at time t. Terms used to describe automatic segmentation according to the invention is defined as follows.

(j,k): Position of a macroblock 15 in the Video Object Plane (VOP) 14 currently being encoded. The coordinates (j,k) represent the upper left corner of the macroblock 15. The size of a macroblock is $B_h \times B_v$ pixels, where B_h is the horizontal dimension and B_v is the vertical dimension of the macroblock, respectively.

MBType(j,k) : Macroblock type. This quantity takes the value INTRA, INTER1V (one motion vector for the whole macroblock), INTER4V (four motion vectors for each of the 8x8 blocks in the macroblock), MOSAIC, SKIP and TRANSPARENT. The INTRA macroblock type corresponds to no prediction from the previous VOP 16 because there are no good matches between the macroblock 15 and any encoded/decoded 16 x 16 pixel image in VOP 16. INTRA macroblocks typically occur when new image areas appear in VOP 14 that cannot be predicted. Instead of encoding the differences between macroblock 15 and the best

matched 16 x 16 pixel image in VOP 16, the macroblock 15 is encoded by itself. (equivalent to using a prediction signal equal to 0)

Referring to FIG. 2, the INTER1V macroblock type corresponds to a prediction from the previous decoded VOP 16 at time t-1. In this case, a prediction signal is computed using one motion vector 17 to align the current macroblock 15 (j,k) with a 16x16 pixel array 18 in a previously encoded VOP 16. The motion vector is the pixel distance that macroblock 15 is shifted from the (j,k) position in VOP 14 to match up with a similar 16 x 16 pixel image in VOP 16. The prediction signal is obtained by applying a local motion vectors to the current macroblock 15 that map to the 16 x 16 pixel image in the previous VOP 16. To reduce the amount of data transmitted, only the macroblock motion vector and residual are transmitted instead of all pixel information in macroblock 15. Motion vectors move on either a pixel or subpixel resolution with respect to the previous VOP 16.

FIG. 3 shows the INTER4V macroblock type that corresponds to a prediction computed using four motion vectors 19. Each motion vector 19 aligns one sub-macroblock 21 with an 8 x 8 pixel array 20 in the previous VOP 16. FIG. 4, shows the MOSAIC macroblock type corresponding to a prediction made from the mosaic 22 updated last at time t-1. A global motion model aligns the current macroblock 15 with a 16 x 16 pixel array 24 in mosaic 22. The TRANSPARENT macroblock mode relates to object based encoding modes where a portion of an image is blocked out for insertion of subsequent object data. The SKIP macroblock mode is equivalent to MOSAIC macroblock mode for which mosaic residual signal is equal to 0.

The residuals generated from the global and various local motion models are compared. The macroblock is usually tagged as the macroblock type with the smallest residuals. However, the macroblock type selection could follow a different policy without affecting the invention described herein.

Define the various residuals that are used by this invention:

RES(j,k) : The transmitted residual at the macroblock (j,k). This residual results from computing the difference between the predictor (reference) image in either the MOSAIC

(MBType(j, k) = MOSAIC or SKIP) or the previous frame type from VOP 16 (MBType(j,k) = INTER1V, or INTER4V) and the data in the macroblock 15 depending on which macroblock type has been selected. The value of RES(j,k) is 0 if the macroblock is of type INTRA.

GMER(j,k): Global motion estimation residual. The residual at the macroblock (j,k) resulting from backward warping the current macro block and comparing it with the previously decoded VOP 16. The warping is done using the transmitted and decoded global motion parameters (i.e. from a Stationary, Translational model, an Affine model or a Perspective model). The global motion estimation residual is the difference between the macroblock 15 and the global motion compensated pixel array in the previous VOP 16. In other words, the GMER(j,k) is the difference between the macroblock 15 and a corresponding pixel array in the previous block 16 after removing the effects of camera rotation, zoom, perspective angle changes, etc. Global motion parameters are encoded and transmitted with each VOP 18. The calculation of GMER(j,k) is described in further detail in FIG. 8.

QP: The current value of the quantizer step used by the encoder to compress the texture residuals in the macroblock (j,k). $\theta(\ )$: A pre-defined threshold value greater or equal to 1. This threshold value is a function of the quantizer step QP. $W_f(\ )$: Forward warping operator. $W_b(\ )$: Backward warping operator. $\underline{w}$: Vector of warping parameters specifying the mappings $W_f(\ )$ and $W_b(\ )$. The vector $\underline{w}$ has zero, two, six or eight entries depending whether the warping is an identity, a translational, an affine or a perspective transformation, respectively. α : A pre-defined blending factor. Warping operators compensate an image for changes in camera perspective, such as rotation, zoom, etc. Implementation of warping operators is well known in the art and, therefore, is not described in further detail.

FIG. 5A shows functional blocks in an automatic segmentation encoder 25 and FIG. 5B shows functional blocks in an automatic segmentation decoder 35 according to the

invention. A camera 26 generates VOPs 18 (see FIG. 1) and a macroblock separator 28 tiles the current VOP 14 into multiple macroblocks 15. A frame predictor 29 matches each individual macroblock 15 with pixel arrays in the previously encoded/decoded VOP frame 16 and generates frame (local) motion vectors and frame residuals associated with the macroblocks in the current VOP 14. Frame predictor 29 is used for assessing INTER1V and INTER4V prediction.

A mosaic predictor 33 matches the macroblocks 15 with pixel arrays in the mosaic 22 by using Global Motion Parameters calculated by Global Motion Estimation and Encoding Unit 27. Such parameters are estimated using original VOPs at time t and t-1 (41). The mosaic predictor 33 produces mosaic residuals associated with each macroblock 15. A global residual computation unit 31 matches the macroblocks with pixel arrays in the previously decoded VOP frame 16 according to frame global motion parameters and generates the global motion estimation residuals GMER(j,k). The global motion parameters are decoded by the decoder 47. An encoder 32 tags each macroblock as either TRANSPARENT or MOSAIC or SKIP or INTRA or INTER1V or INTER4V upon comparing the mosaic residual signal and the frame local residuals signals. Encoder 32 also inserts the global motion parameters in the encoded bit stream.

The INTER1V or INTER4V prediction types are alternatively referred to as FRAME prediction types. The foreground/background segmentation and mosaic update unit 43 classifies macroblocks tagged as INTER1V prediction type as foreground when the global motion estimation residuals GMER(j,k) are greater than a portion (specified by the value θ) of the INTER1V residuals RES(j,k). Otherwise, the INTER1V macroblocks are classified as background. INTER4V macroblocks are classified as foreground.

The MOSAIC and SKIP macroblocks are referred to as MOSAIC prediction types. These macroblocks are classified as background.

The INTRA macroblocks are classified as foreground.

The mosaic update unit 43 identifies the background and foreground macroblocks and blends the macroblocks classified as background into the mosaic 22. The encoder 32 can then

transmit an encoded bit stream including the global motion parameters, the tagged macroblock prediction type, the motion vectors associated with the tagged macroblock prediction type (if the macroblock type demands it), and the residuals associated with the tagged macroblock prediction type. A decoder 30 decodes the encoded bit stream to generate the decoded previous frame 16.

The decoder 35 includes a macroblock detector 38 that reads the tagged macroblock prediction type in the transmitted bit stream transmitted by encoder 25. The bitstream data is directed to the relevant decoder depending on the macroblock type. A frame decoder 37 uses the received residuals and portions of the previous decoded VOP 16 to reconstruct INTER1V or INTER4V macroblocks. A mosaic decoder 45 uses the received residuals and portions of the mosaic 22 to reconstruct MOSAIC or SKIP macroblock types. The macroblock decoder and assembler 39 takes the output of the frame decoder or the mosaic decoder as appropriate. Neither of these two predictors is used for INTRA macroblocks and in this case decoder 39 decodes the INTRA macroblock. A global residual computation unit 31 receives the decoded global motion parameters associated with the current frame. These global motion parameters are decoded by unit 47.

The residual signal and macroblock type used by decoder 39 are also passed to the foreground/background segmentation and mosaic update unit 49 to classify the macroblocks as foreground or background. The output of the global residual computation unit 31 is also input to the mosaic update unit 49. The exact same rules are used as in the encoder to derive the foreground/background segmentation map. Specifically, decoded INTER1V prediction type macroblocks are classified as foreground when the global motion estimation residuals GMER(j,k) are greater than the portion of the INTER1V residual RES(j,k). Otherwise, the assembled macroblocks are classified as background. Decoded INTRA and INTER4V macroblock types are classified as foreground. MOSAIC and SKIP macroblocks are classified as background. The mosaic update unit 49 updates the mosaic 22 with assembled macroblocks classified as background.

FIG. 6 describes the overall operation of the automatic segmentation encoder 25 according to the invention.

Step 1: Initialize sprite

$$S_t(\underline{R},t_0) = \begin{cases} VO_t(\underline{r},t_0) & if \quad VO_s(\underline{r},t_0) == 1 \\ 0 & otherwise \end{cases}$$

$$S_s(\underline{R},t_0) = \begin{cases} 1 & if \quad VO_s(\underline{r},t_0) == 1 \\ 0 & otherwise \end{cases}$$

where $S_s()$, $S_t()$, $VO_s()$, $VO_t()$ represent the sprite (mosaic) shape, the sprite texture, the decoded VOP shape (rectangular shaped VO here) and the decoded VOP texture fields, respectively. The sprite shape $S_s(\ )$ and the decoded VOP shape $VO_s(\ )$ are binary fields. In the sprite shape image, the value 0 means that the mosaic content is not determined and the value 1 means the mosaic content is determined at this location. In the decoded VO shape image, values 0 and 1 mean that the decoded VO is not defined and defined at this location, respectively. Position vectors $\underline{R}$ and $\underline{r}$ represent the pixel position in the sprite and in the VO, respectively.

The content of the mosaic 22 is initialized with the content of the first VOP 16. The shape of the sprite is initialized to 1 over a region corresponding to the rectangular shape of VOP 16. The value 1 indicates that texture content has been loaded at this location in the mosaic. Instead of dumping the first VOP 16 into mosaic 22, an alternative initialization process is to initialize the buffers $S_s(\ )$ and $S_t(\ )$ to 0 thereby delaying integration of VOP 14 content into the mosaic by one image. The benefit of such approach is to avoid taking foreground information in the first VOP to initialize the mosaic. The automatic segmentation mode discussed below is the implementation for any macroblock inserted into the mosaic 22.

Step 2: Acquire next VOP (time t) and select macroblock type.

The macroblocks 15 are backward warped $W_b(\ )$ and then matched with corresponding pixel arrays in mosaic 22. The difference between macroblock 15 and the mosaic 22 are the residuals for the MOSAIC macroblock type. The same backward mapping is used to record the residuals GEMR(j,k) obtained from the previous decoded VOP 16. The macroblock 15 is compared with similar sized pixel arrays in previous VOP 16. A macroblock local motion vector maps macroblock 15 to a pixel array in previous VOP 16 to derive INTER1V residuals. Four local motion vectors are used to derive residual values for the INTER4V macroblock type.

If the residual values for MOSAIC, INTER1V and INTER4V are all greater than a predefined threshold, the macroblock 15 is assigned to MBType(j,k) = INTRA. If one or more of the residual values are below the threshold value, the macroblock 15 is assigned to the MBType(j,k) with the smallest frame or mosaic residual. Note that other policies can be implemented to select the macroblock type without affecting the invention described herein.

Step 3: Encode and decode the VOP

The encoder 25 encodes and decodes the VOP 14 at time (t). The bitstream representing the encoded VOP is transmitted to the decoder. The decoder 30 (FIG. 5A) decodes the encoded bitstream to generate the decoded VOP 14.

Step 4: Create binary map to detect macroblocks belonging to foreground

Referring to FIG. 7 and 9, for every macroblock (j,k) in the current decoded rectangular-shaped VOP 14, an object segmentation map g(j,k) 72 is built. The encoder 25 extracts a macroblock from the current VOP 14 in step 40. Decision step 42 tests whether the macroblock is of type MOSAIC or SKIP. If the macroblock is of type MOSAIC or of a type SKIP, the segmentation map 72 is set to zero in step 44.

if((MBType(j,k) = = MOSAIC) || (MBType(j,k) = SKIP)).

{

$$g(j,k) = 0$$

}

If decision step 46 determines the macroblock is of type INTER4V or INTRA, the segmentation map is set to 1 in step 48.

else if(MBType(j,k) == INTER4V)

{

$$g(j,k) = 1$$

}

If the macroblock is not of types MOSAIC, INTER4V, INTRA or SKIP, the global motion estimation residual (obtained from applying the global motion parameters between the decoded VOP at time t and the decoded VOP at time t-1) is compared against the residual from the INTER1V macroblock type in decision step 50. If the global motion estimation residual is greater than some portion of the INTER1V residual (set by $\theta(QP)$), the corresponding macroblock in segmentation map 72 is set to 1 in step 52. If the Global Motion Estimation Residual is not greater, the segmentation map is set to 0 in step 54.

if($GMER(j,k) > \theta(QP) RES(j,k)$)

{

$$g(j,k) = 1$$

}

else

{

$$g(j,k) = 0$$

}

}

The binary segmentation map 72 $g(j,k)$ represents initial foreground/background segmentation. Detected foreground texture is denoted by setting $g(j,k) = 1$. This is the case whenever the INTER4V macroblock occurs since it corresponds to the situation where there are four distinct and local motion vectors. In other words, the four different motion vectors indicate that the image in the macroblock is not background. INTRA macroblocks are also considered foreground ($g(j,k) = 1$) because the macroblock cannot be predicted from the previous decoded VOP or the mosaic. INTER1V are tagged as foreground when global motion estimation residual GMER(j,k) is larger than the portion of the (transmitted) INTER1V residual RES(j,k). In this situation, the global motion model does not correspond to the local dynamics of the foreground object.

FIG. 8 explains in further detail how the encoder 25 (FIG. 5A) distinguishes background from foreground in the INTER1V macroblocks. The macroblock 15 in VOP 14 is determined by the encoder 25 to be of type INTER1V. Although macroblock 15 is encoded as INTER1V type, it is not conclusive whether the INTER1V type was used because macroblock 15 contains a foreground image or because the mosaic 22 is either corrupted with foreground content or has not completely incorporated that portion of background image contained in macroblock 15.

The global motion parameters for VOP 14 are applied to macroblock 15 in box 58. The INTER1V local motion vector is applied to macroblock 15 in block 56. A pixel array 55 corresponding to the global motion vector is compared to the macroblock 15 to generate the global motion estimation residual GMER(j,k) in block 62. The pixel array 18 corresponding to the INTER1V local motion vector is compared to the macroblock 15 generating the INTER1V residual $RES(j,k)$ in block 64. The global motion estimation residual GMER(j,k) and the INTER1V residual $RES(j,k)$ are compared in block 66.

If the global residual $GMER(j,k)$ is greater than some portion of the INTER1V residual $RES(j,k)$, the image in the macroblock 15 has its own motion and does not correspond to the global motion induced by panning, zooming, etc. of the camera.

Accordingly, the image in macroblock 15 is tagged as foreground in block 68. Conversely, when the INTER1V residual $RES(j,k)$ is greater than the global residual $GMER(j,k)$, the image in the macroblock 15 tagged as background because it is likely to be new content in the background or a better representation of the background than what is currently in the mosaic 22.. The macroblocks 15 tagged as background are inserted into the mosaic 22.

Step 5: Process segmentation map to make regions more homogeneous

Step 5 (FIG. 6) removes any isolated 1s or 0s in the binary segmentation map 72 g( ) by using a two-dimensional separable or non-separable rank filter. The filter uses a neighborhood of macroblocks Ω around a macroblock 74 of interest at location (j,k). M specifies the number of macroblocks in this neighborhood. The values of the segmentation map g( ) for each of the macroblocks belonging to the neighborhood Ω are ranked in increasing order in an array A with M entries.

Since g( ) can only take the value 0 or 1, A is an array of M bits where there are K zeros followed by (M-K) ones, K being the number of times the map g( ) takes the value 0 in the neighborhood Ω. Given a pre-fixed rank ρ, $1 \leq \rho \leq M$, the output of the filter is selected as the ρ th entry in the array A, that is A[ρ]. The output of the filter at each macroblock location (j,k) is used to generate a second segmentation map h(), such that h(j,k) = A[ρ]. The result of applying the filter to the segmentation map g() is removal of spurious 1's or 0's in the initial segmentation, thereby making it more spatially homogeneous. If the filter is separable, the filtering operation above repeated along each dimension (horizontally then vertically or vice versa). At the end of the first pass, the output map h() is copied to the map g() before the second pass is started.

Referring to FIG. 9, the number M of macroblocks in the neighborhood is 9. For the target macroblock 74, the array A has 9 entries with 8 zeros in macroblocks g(32,0), g(48,0), g(64,0), g(32,16), g(64,16), g(32,32), g(48,32) and g(64,32) followed by a 1 at macroblock g(48,16) (assuming a macroblock size of 16 pixels vertically and horizontally). Pre-fixed

rank ρ is set at 7 and the output of the filter at the 7th entry in the array A is 0. The filtered output of the macroblock 74 is, therefore, zero. A second filtered segmentation map 76 is generated from the filtered segmentation map 72.

Step 6: Update mosaic according to new segmentation map

Referring to FIG. 10, for every macroblock (j,k) in the current VOP 14 at time (t), the mosaic 22 is updated as follows. First, the mosaic shape at time t, $S_s(\underline{R},t)$, is equal to 0 everywhere. Next, given a macroblock position (j,k), let $\underline{r} = \begin{bmatrix} j+l \\ k+p \end{bmatrix}$ where the variables l and p are such that $0 \le l \le B_h - 1$ and $0 \le p \le B_v - 1$. The variables $j+l$ and $k+p$ are used to denote the position of each pixel within the macroblock (j,k).

The first macroblock is referenced in step 77 and the first pixel in the macroblock is retrieved in step 78. For every value l and p in the range specified above the following operation is performed. The pixels in the macroblock 15 are tested in step 80 to determine whether the pixel belongs to the decoded VOP 16 and whether mosaic content at this pixel location is already determined.

if($(VO_s(\underline{r},t)==1) \&\& (S_s(\underline{R},t-1)==1)$)

{

Decision step 82 determines whether the macroblock 15 is classified as a foreground macroblock. If the pixel in macroblock 15 is tagged as foreground, the corresponding pixel array in mosaic 22 is warped forward in step 84 but its contents are not changed.

if($h(j,k) == 1$)

{

$$S_t(\underline{R},t) = W_f\left(S_t(\underline{R},t-1),\underline{w}\right)$$

}

If the macroblock is tagged as background, the mosaic is forward warped and updated by blending the current content of VOP 14 in step 86.

{

$$S_t(\underline{R},t)=(1-\alpha)W_f\left(S_t(\underline{R},t-1),\underline{w}\right)+\alpha\, VO_t(\underline{r},t)$$

}

where α specifies the blending factor. The shape of the mosaic is set to 1 in step 92 to signal that mosaic content at that location has been determined.

$$S_s(\underline{R},t)=1$$

}

If the macroblock pixel belongs to the VOP 16, the content of the mosaic 22 is undetermined (88), and the macroblock is classified as background (89) the content of the mosaic is set to the content of the current pixel in the VOP 14 in step 90 and the mosaic shape is set to 1 in step 92.

else if($(VO_s(\underline{r},t)==1)\&\&(S_s(\underline{R},t-1)==0)$)

{

if(h(j,k) == 0){

$$S_t(\underline{R},t)= VO_t(\underline{r},t)$$

$$S_s(\underline{R},t)=1$$

}

}

After all pixels in the current macroblock 15 have been processed in decision step 93, step 94 gets the next macroblock. Otherwise, the next pixel is retrieved in step 78 and the process described above is repeated.

Step 7: Acquire next VOP

The encoder 26 goes back to step 2 (FIG. 6) to start the same procedure for the next VOP at time t=t+1.

Automatic Segmentation in a Non-Coding Environment

The automatic segmentation described above can also be used in a non-coding environment. In this case, the macroblock sizes B_h and B_v are no longer imposed by the video coder 26 and are adjusted based on other criteria such as image resolution and object shape complexity. In this case, block-based image processing provides increased robustness in the segmentation by preventing spurious local motion modes to be interpreted as global motion of the background object. Furthermore, the value of the threshold $\theta(\ )$ is no longer a function of a quantizer step but instead becomes a function of the noise level in the video

The automatic segmentation for on-line sprite-based coding is used in MPEG-4 codecs supporting on-line sprite prediction. It can also be used in digital cameras and camcorders to generate panoramic images. These panoramic images can be used to enhance consumer viewing experience (with or without foreground objects) and can also be used as representative images in a consumer video database (to summarize a video segment that includes camera panning, for example). It can be used as a basis for an image resolution enhancement system in digital cameras as well. In this case, a warping operation is designed to include a zooming parameter that matches the desired final resolution of the mosaic.

Having described and illustrated the principles of the invention in a preferred embodiment thereof, it should be apparent that the invention can be modified in arrangement and detail without departing from such principles. I claim all modifications and variation coming within the spirit and scope of the following claims.

Claims

1. A method for automatically segmenting foreground and background objects in images, comprising:

encoding and decoding a first image at a first time reference;

extracting macroblocks from a second image at a second time reference;

mapping the macroblocks with corresponding arrays in the decoded first image according to a macroblock local vector;

deriving frame residuals between the macroblocks and the corresponding arrays;

mapping macroblocks to the first image according to a global motion model;

deriving global residuals between the macroblocks and the corresponding global motion compensated array in the first image;

tagging the macroblocks as a frame prediction type based on one local motion vector; and

classifying the macroblocks as foreground or background by comparing the global residuals with the derived frame residuals.

2. A method according to claim 1 including the following:

mapping the macroblocks with corresponding image arrays in a mosaic;

deriving mosaic residuals between the macroblocks and the corresponding mosaic image arrays;

tagging the macroblocks as a mosaic prediction type; and

classifying the mosaic prediction type macroblocks as background.

3. A method according to claim 2 including the following:

matching subportions of the macroblocks with subimage arrays in the decoded first image;

deriving multiple local motion vectors mapping the different subportions of the macroblocks to the matched subimage arrays;

deriving residuals for the subportions between the subportions of the macroblocks and the matched subimage arrays;

tagging macroblocks as a submacroblock prediction type based on multiple local motion vectors; and

classifying the submacroblock prediction type macroblocks as foreground.

4. A method according to claim 3 including tagging macroblocks as an intracoded prediction type when the macroblocks are encoded without using prediction.

5. A method according to claim 1 including the following:

classifying the macroblocks as foreground when the global residuals are greater than a function of the frame residuals;

classifying the macroblocks as background when the frame residuals are greater than some function of the global residuals; and

updating the mosaic with macroblocks tagged as background.

6. A method according to claim 4 including transmitting an encoded bit stream that includes the tagged prediction type of the macroblocks, local motion vectors and global motion parameters mapping the macroblocks to the tagged prediction type and the residuals for the tagged prediction type.

7. A method according to claim 5 including the following:

creating a segmentation map that identifies the macroblocks in the second image as either foreground or background;

smoothing the segmentation map to remove extraneous foreground and background macroblocks in the segmentation map; and

updating the mosaic with the identified background macroblocks in the smoothed segmentation map.

8. A method according to claim 7 wherein smoothing the segmentation map includes the following:

taking macroblock neighbors around a target macroblock in the segmentation map;

taking the segmentation map values for each of the macroblock neighbors and the target macroblock;

ranking the segmentation map values in increasing order; and

selecting the output of the target macroblock as the value of the ranked neighbor at a selected threshold.

9. A method according to claim 8 including forward warping the mosaic but not changing the contents of the mosaic when all of the following conditions occur:

pixel sample values in the macroblocks belong to a decoded VOP;

the mosaic content is already determined at the pixel locations; and

the macroblock is labeled as foreground.

10. A method according to claim 9 including forward warping the mosaic and blending the pixel sample values into the mosaic when all of the following conditions occur:

pixels in the macroblock belong to the decoded VOP;

the mosaic content is already determined at the pixel locations; and

the macroblock is labeled as background.

11. A method according to claim 10 including forward warping and updating the mosaic content with content of the pixel sample values in the decoded second image when all of the following conditions occur:

pixels in the macroblock belong to the decoded second image;

the mosaic content is undetermined at the pixel locations; and

the macroblock is labeled as background.

12. A method according to claim 11 including tagging the pixel locations in the mosaic shape to indicate the mosaic content is determined.

13. A method according to claim 12 including initializing a mosaic by either inserting the first decoded image into the mosaic and then updating the mosaic in time only with macroblocks classified as background or setting a mosaic buffer to zero everywhere and then incrementally updating the mosaic in time only with macroblocks classified as background.

14. An automatic segmentation system for mosaic based encoding, comprising:

a macroblock separator separating a frame into multiple macroblocks;

a frame predictor matching the macroblocks with pixel arrays in a previously decoded frame according to local motion vectors and generating frame residuals associated with the macroblocks;

a mosaic predictor matching the macroblocks with pixel arrays in a mosaic according to global motion parameters and generating residuals associated with the macroblocks;

a global motion predictor matching the macroblocks with pixel arrays in the previously decoded frame according to frame global motion parameters and generating a global residual; and

a macroblock encoder tagging the macroblocks as mosaic prediction type when the mosaic residuals are used for encoding the macroblocks, and tagging the macroblocks as frame prediction type based on a local motion vector when the frame residuals are used for encoding the macroblocks, the macroblock encoder classifying the frame prediction type macroblocks as either foreground or background by comparing the global residuals with the frame residuals and classifying the mosaic prediction type as background.

15. An automatic segmentation system according to claim 14 wherein the macroblock encoder blends the macroblocks classified as background into the mosaic.

16. An automatic segmentation system according to claim 15 wherein the macroblock encoder transmits an encoded bit stream including the tagged macroblock prediction type, the motion vectors associated with the tagged macroblock prediction type, and the residuals associated with the tagged macroblock prediction type.

17. An automatic segmentation system according to claim 16 including a decoder having the following:

a macroblock detector detecting the tagged macroblock prediction type in the encoded bit stream;

a frame decoder reconstructing macroblocks tagged as frame prediction type according to a previously decoded decoder frame;

a mosaic decoder reconstructing macroblocks tagged as mosaic prediction type according to a mosaic reconstructed in the decoder; and

a decoder reconstructing macroblocks tagged as intracoded.

18. An automatic segmentation system according to claim 17 including a global decoder receiving global motion parameters for a current frame and classifying assembled frame prediction type macroblocks as foreground when the global residuals are greater than a function of the macroblock frame residuals and otherwise classifying the assembled macroblocks as background.

19. An automatic segmentation system according to claim 18 wherein the macroblock decoder classifies the macroblocks as background or foreground according to the tagged prediction type.

20. An automatic segmentation system according to claim 19 wherein the macroblock decoder tags the macroblocks according to the following:

INVER1V frame prediction type for the macroblocks having a single local motion vector;

INTER4V frame prediction type for the macroblocks having multiple local motion vectors;

MOSAIC prediction type for the macroblocks predicted according to global motion parameters;

SKIP prediction type corresponding to a MOSAIC prediction type for which the residual signal is zero;

INTRA prediction type for the macroblocks not using any prediction;

the macroblock encoder classifying INTER4V and INTRA prediction types as foreground, and the MOSAIC and SKIP prediction types as background.

21. An automatic segmentation system according to claim 20 wherein the mosaic decoder updates the decoder mosaic with assembled macroblocks classified as background.

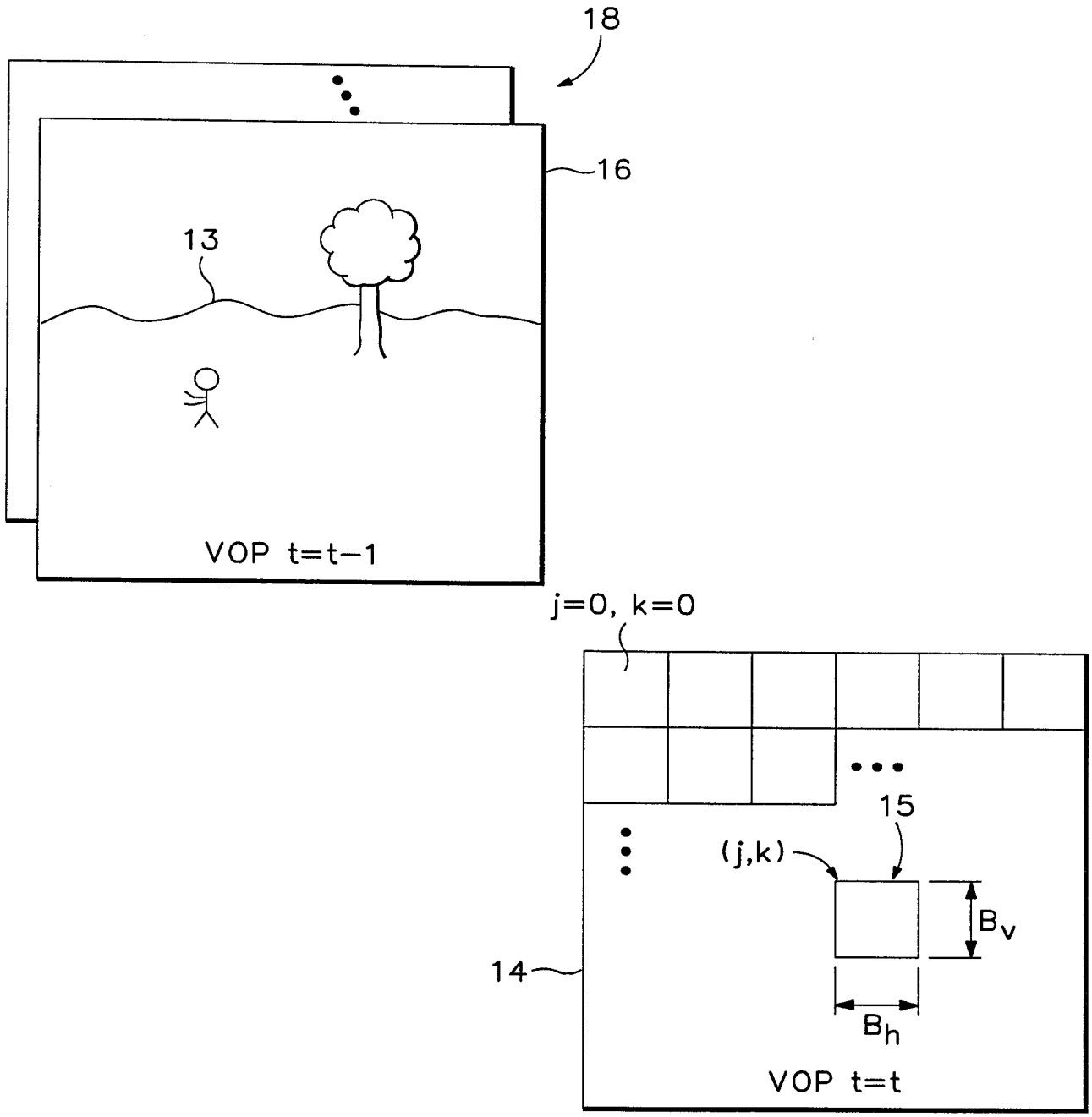


FIG.1

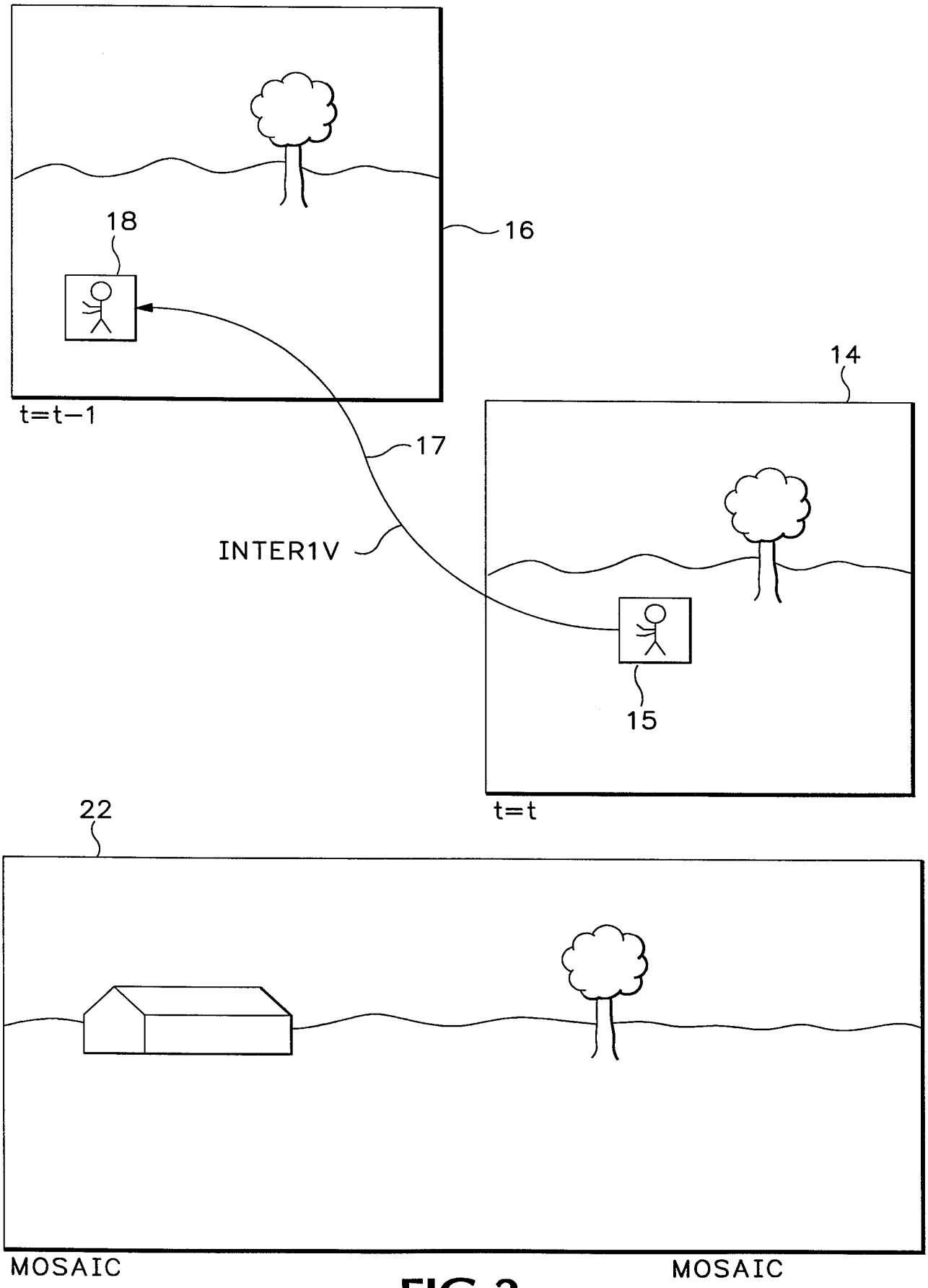


FIG.2

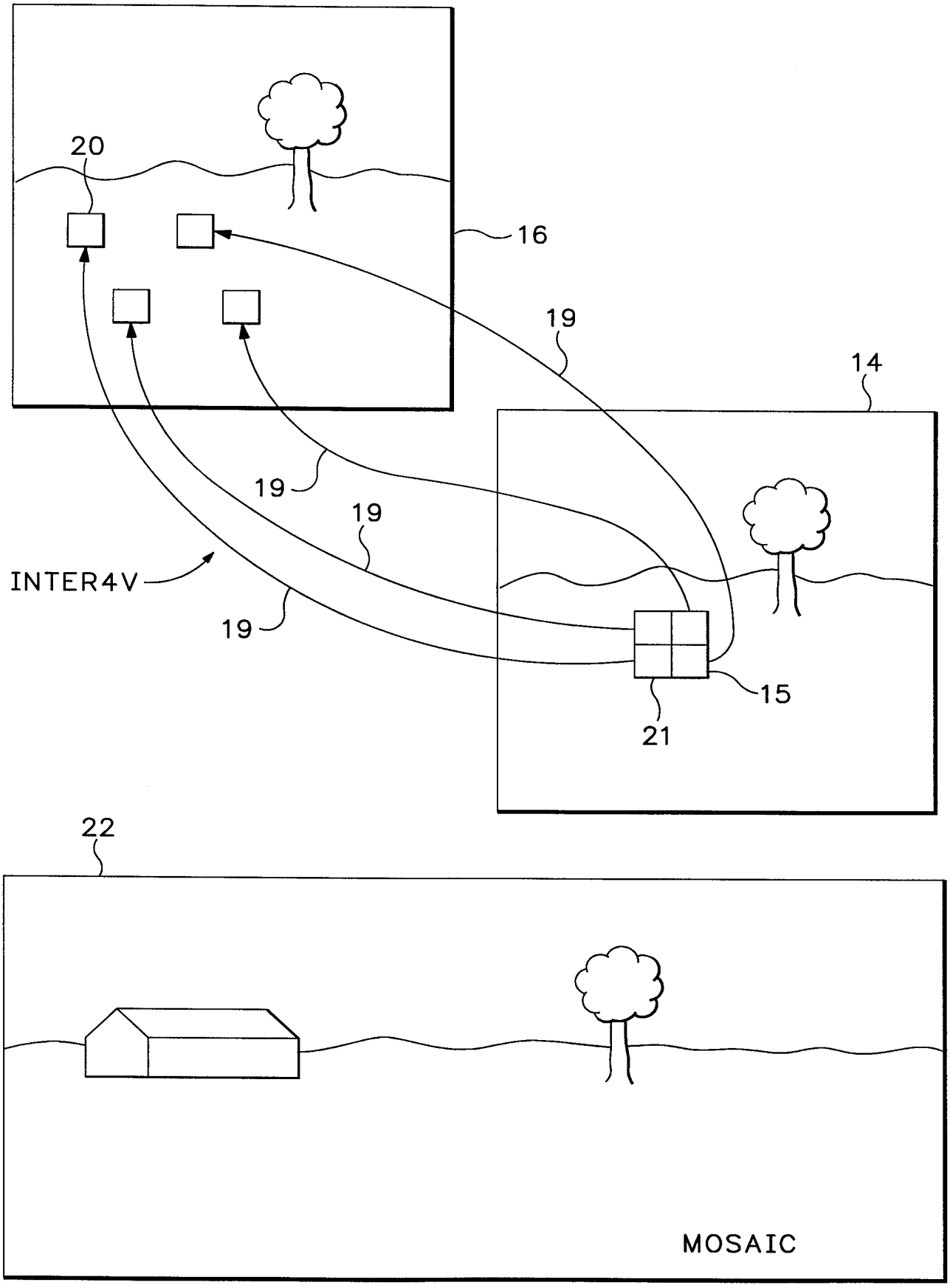


FIG.3

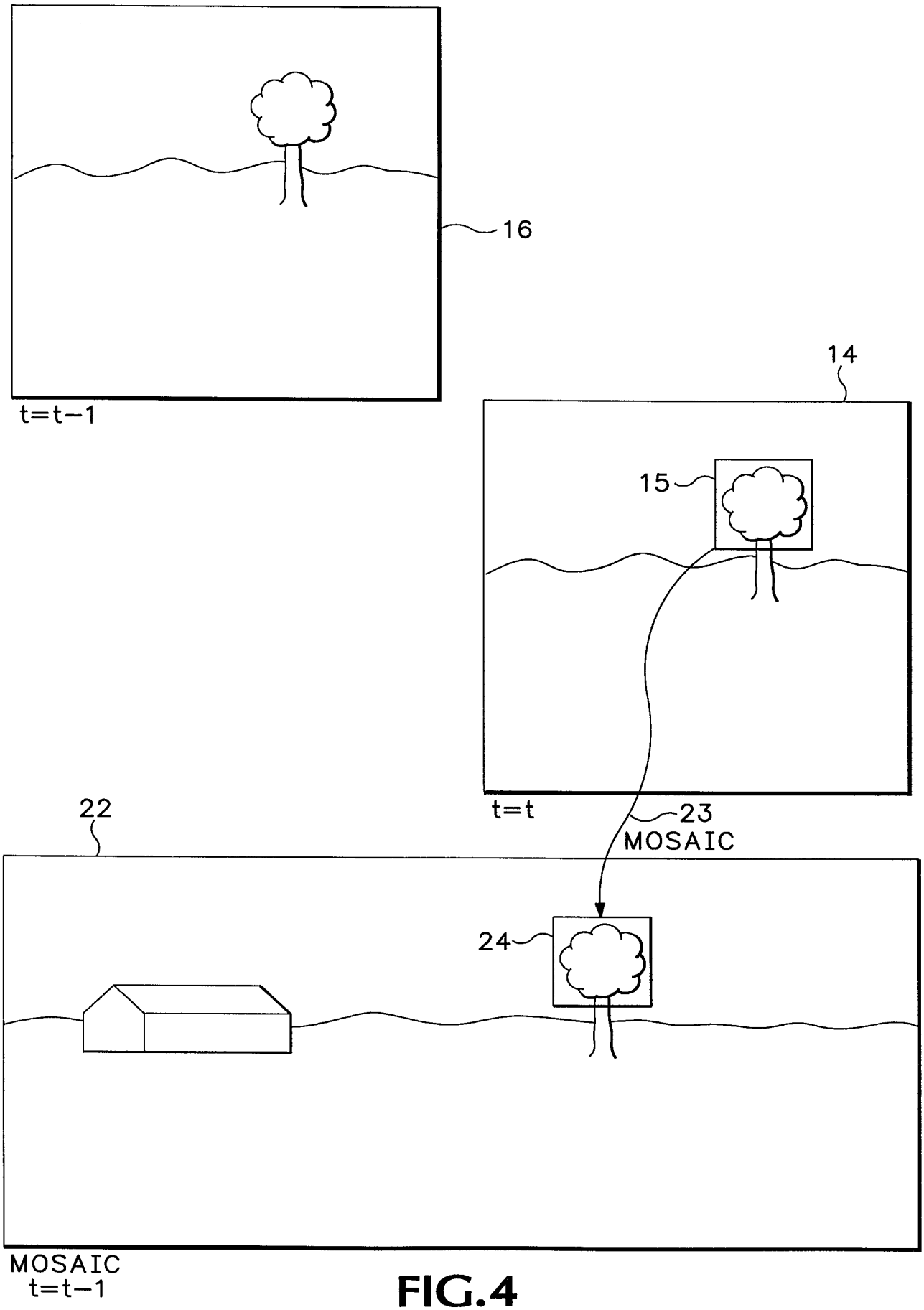


FIG.4

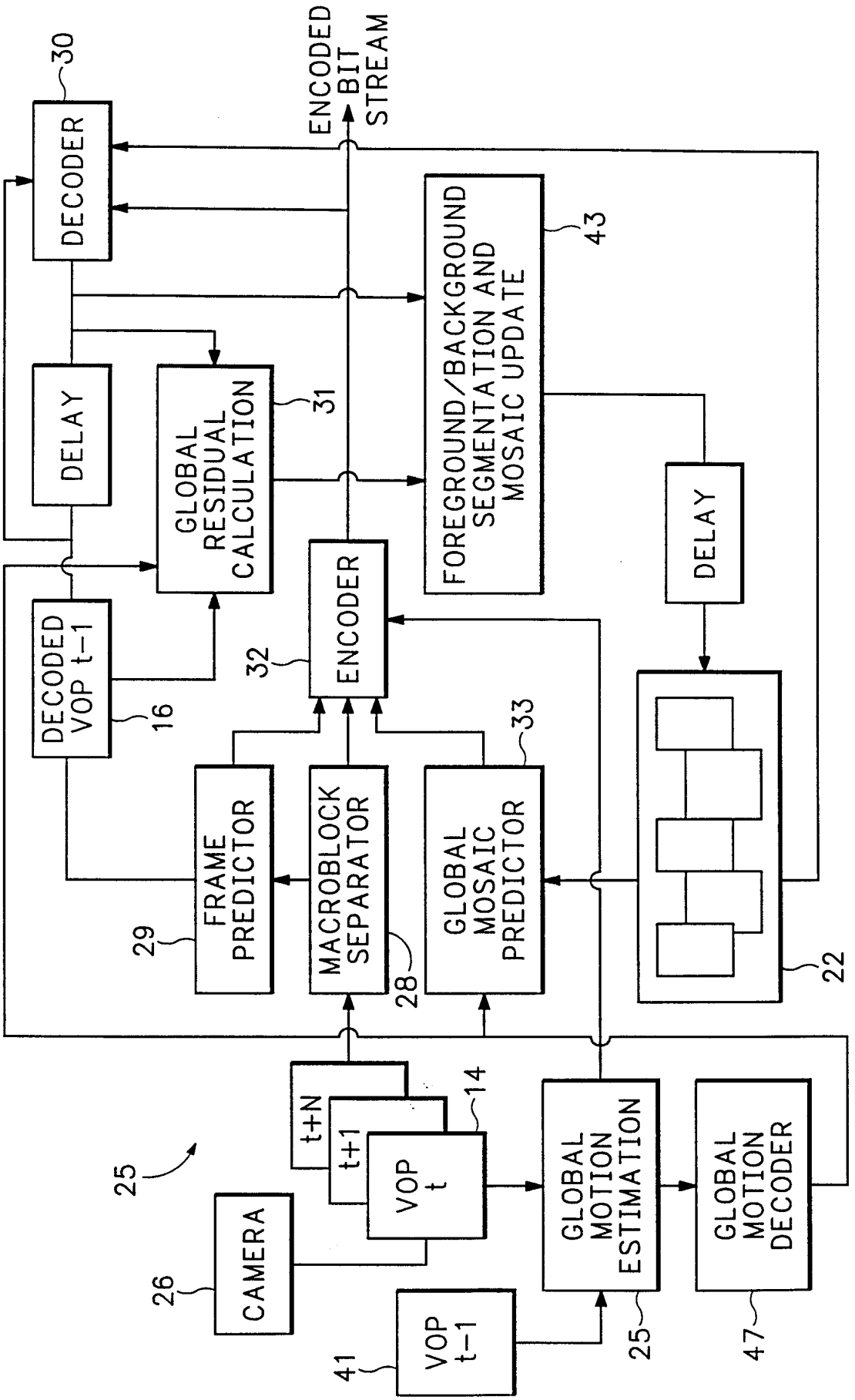

ENCODED BIT STREAM
30
DECODER
DELAY
GLOBAL RESIDUAL CALCULATION
31
FOREGROUND/BACKGROUND SEGMENTATION AND MOSAIC UPDATE
43
DELAY
DECODED VOP t-1
16
32
ENCODER
33
FRAME PREDICTOR
29
MACROBLOCK SEPARATOR
28
GLOBAL MOSAIC PREDICTOR
22
25
t+N
t+1
VOP t
14
CAMERA
26
GLOBAL MOTION ESTIMATION
25
GLOBAL MOTION DECODER
47
VOP t-1
41

FIG.5A

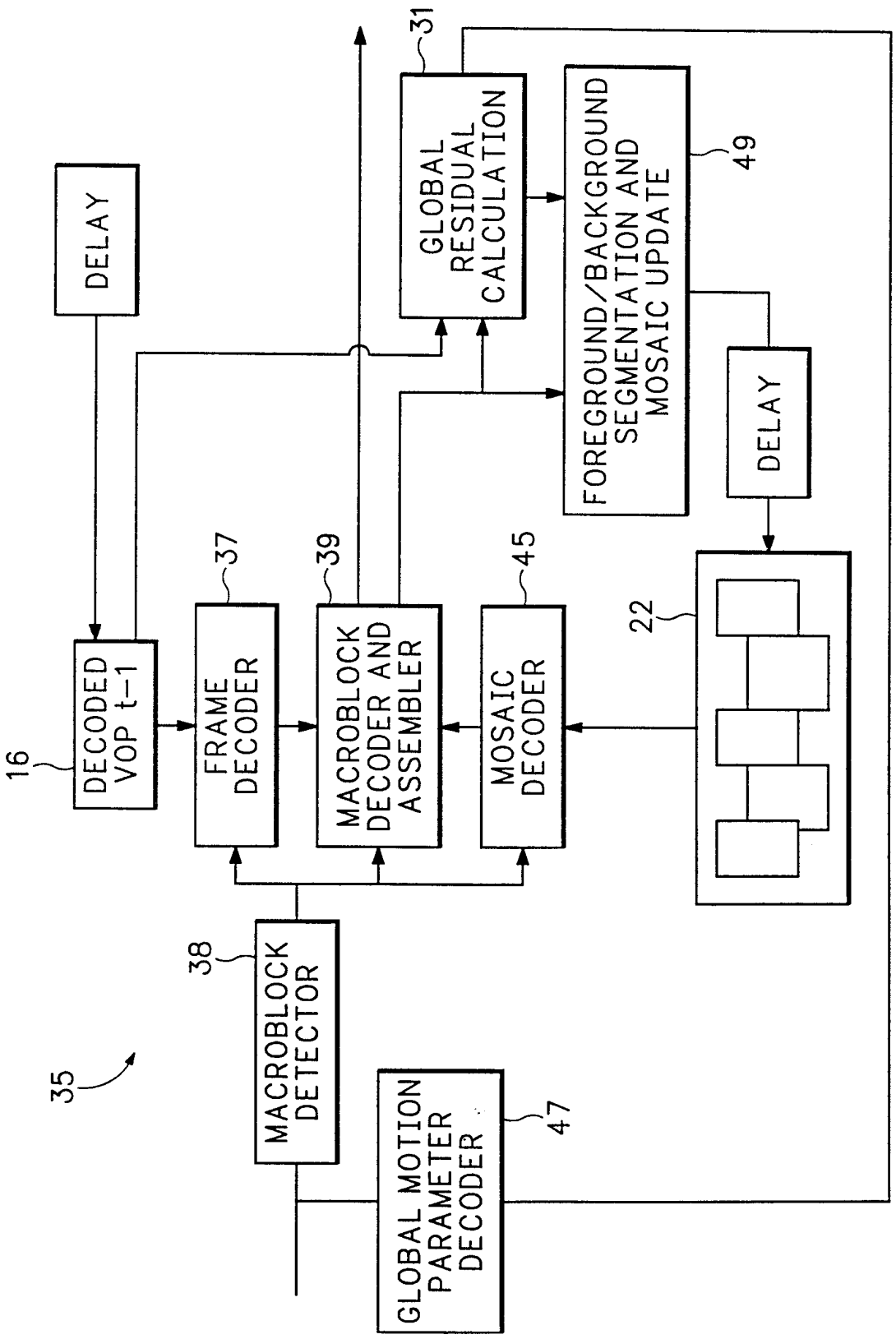

DELAY
GLOBAL RESIDUAL CALCULATION
31
FOREGROUND/BACKGROUND SEGMENTATION AND MOSAIC UPDATE
49
DELAY
22
DECODED VOP t-1
16
FRAME DECODER
37
MACROBLOCK DECODER AND ASSEMBLER
39
MOSAIC DECODER
45
MACROBLOCK DETECTOR
38
GLOBAL MOTION PARAMETER DECODER
47
35

FIG.5B

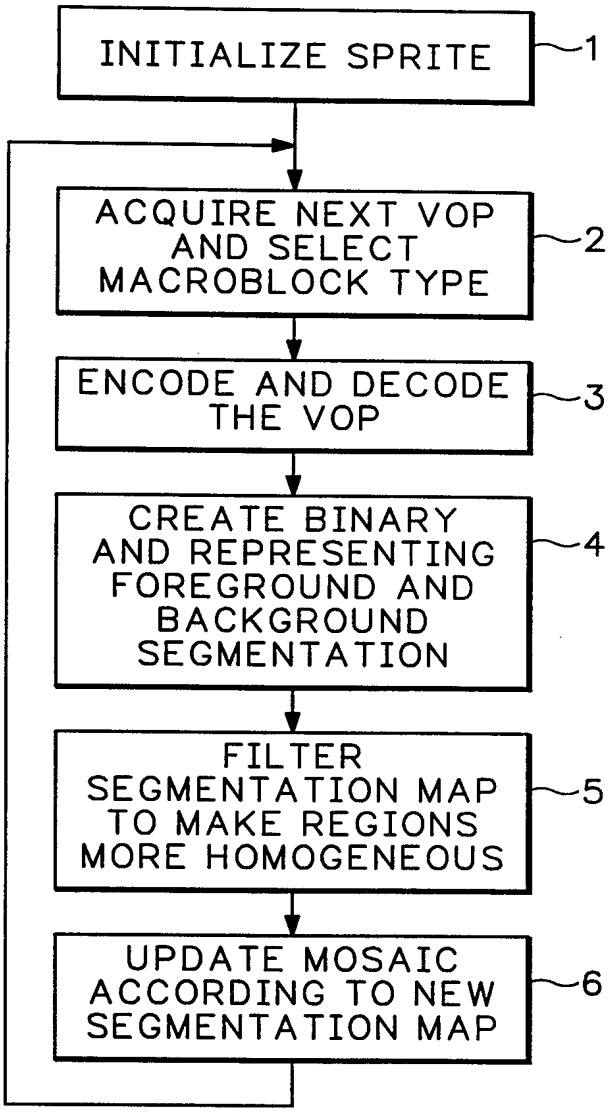

INITIALIZE SPRITE
1
ACQUIRE NEXT VOP AND SELECT MACROBLOCK TYPE
2
ENCODE AND DECODE THE VOP
3
CREATE BINARY AND REPRESENTING FOREGROUND AND BACKGROUND SEGMENTATION
4
FILTER SEGMENTATION MAP TO MAKE REGIONS MORE HOMOGENEOUS
5
UPDATE MOSAIC ACCORDING TO NEW SEGMENTATION MAP
6

FIG.6

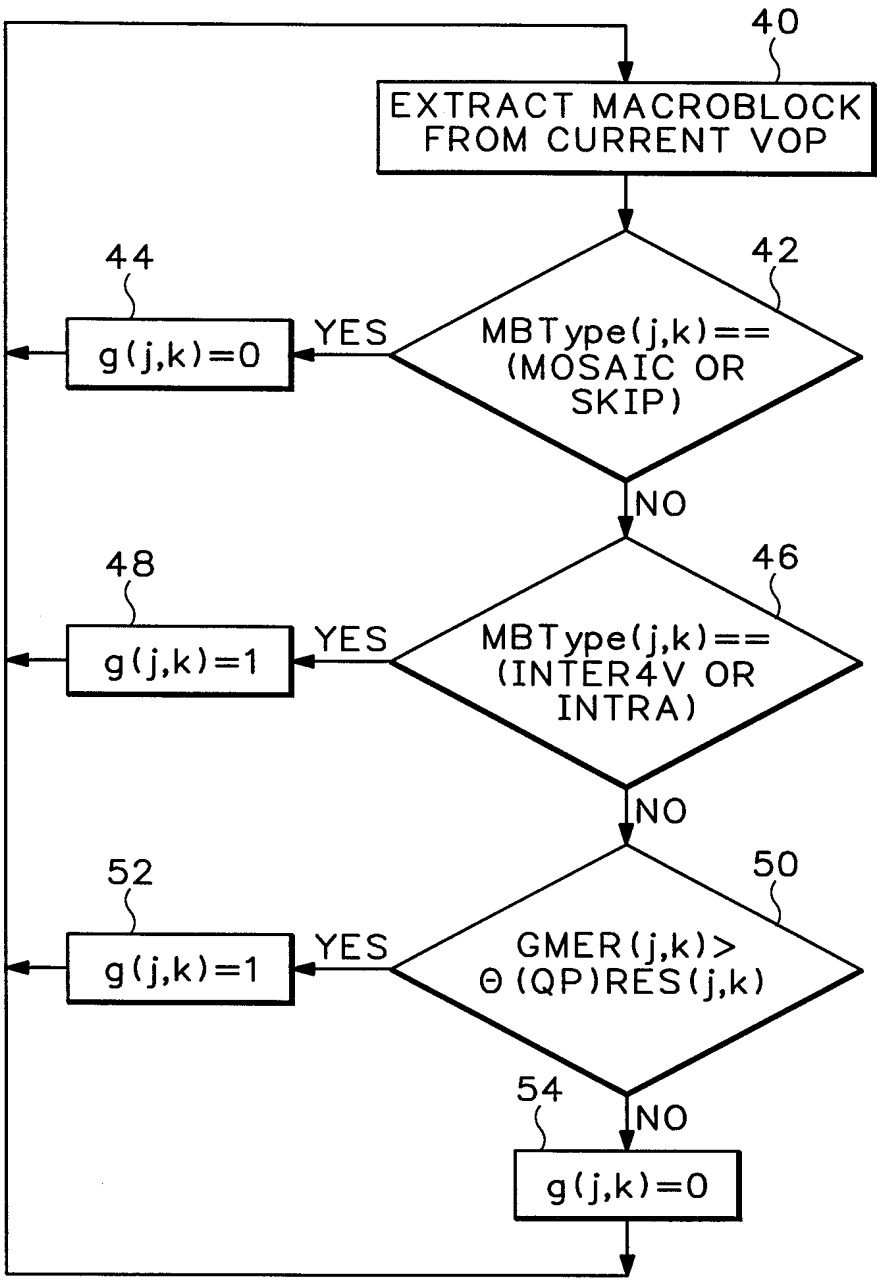

40
EXTRACT MACROBLOCK FROM CURRENT VOP
42
MBType(j,k)== (MOSAIC OR SKIP)
YES
44
g(j,k)=0
NO
46
MBType(j,k)== (INTER4V OR INTRA)
YES
48
g(j,k)=1
NO
50
GMER(j,k)> Θ(QP)RES(j,k)
YES
52
g(j,k)=1
NO
54
g(j,k)=0

FIG.7

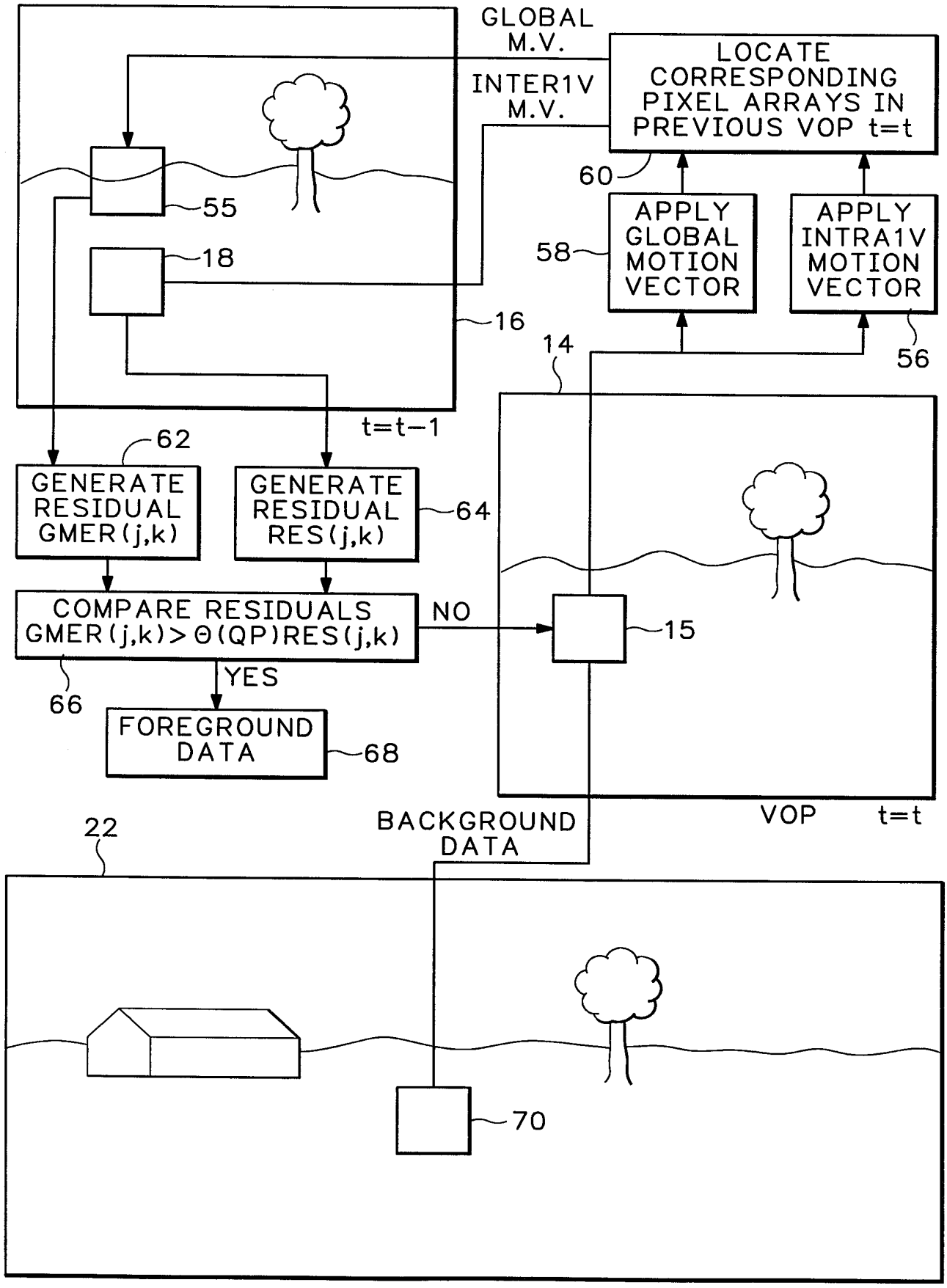


FIG.8

SUBSTITUTE SHEET (RULE 26)

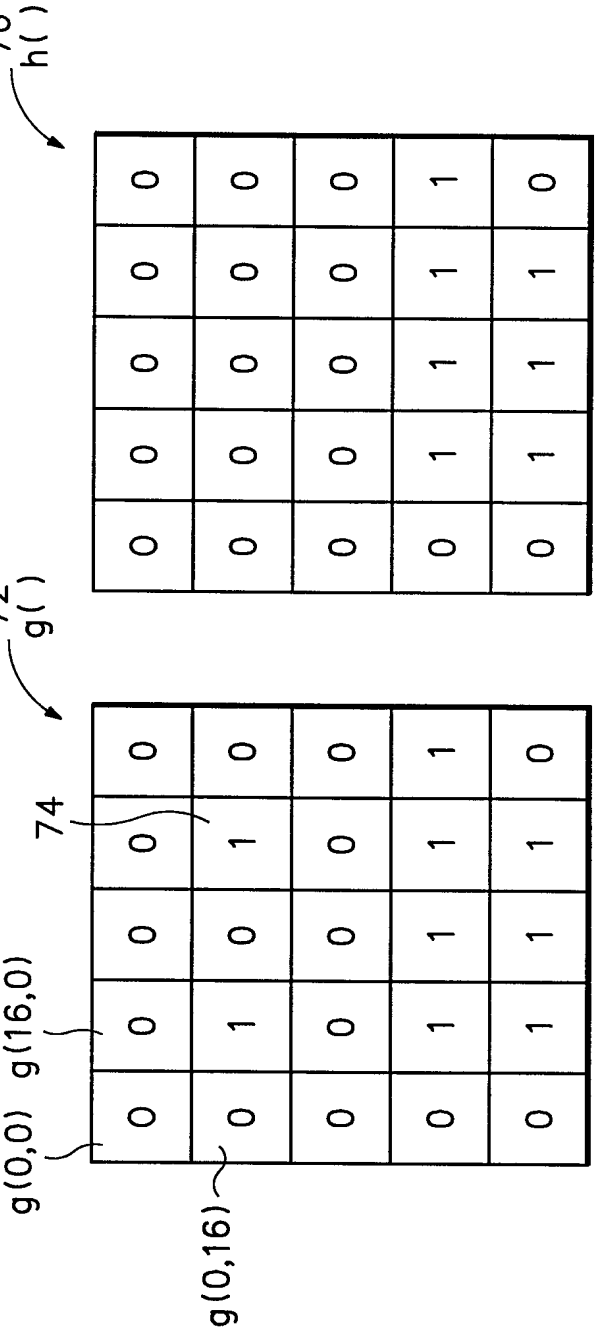


FIG.9

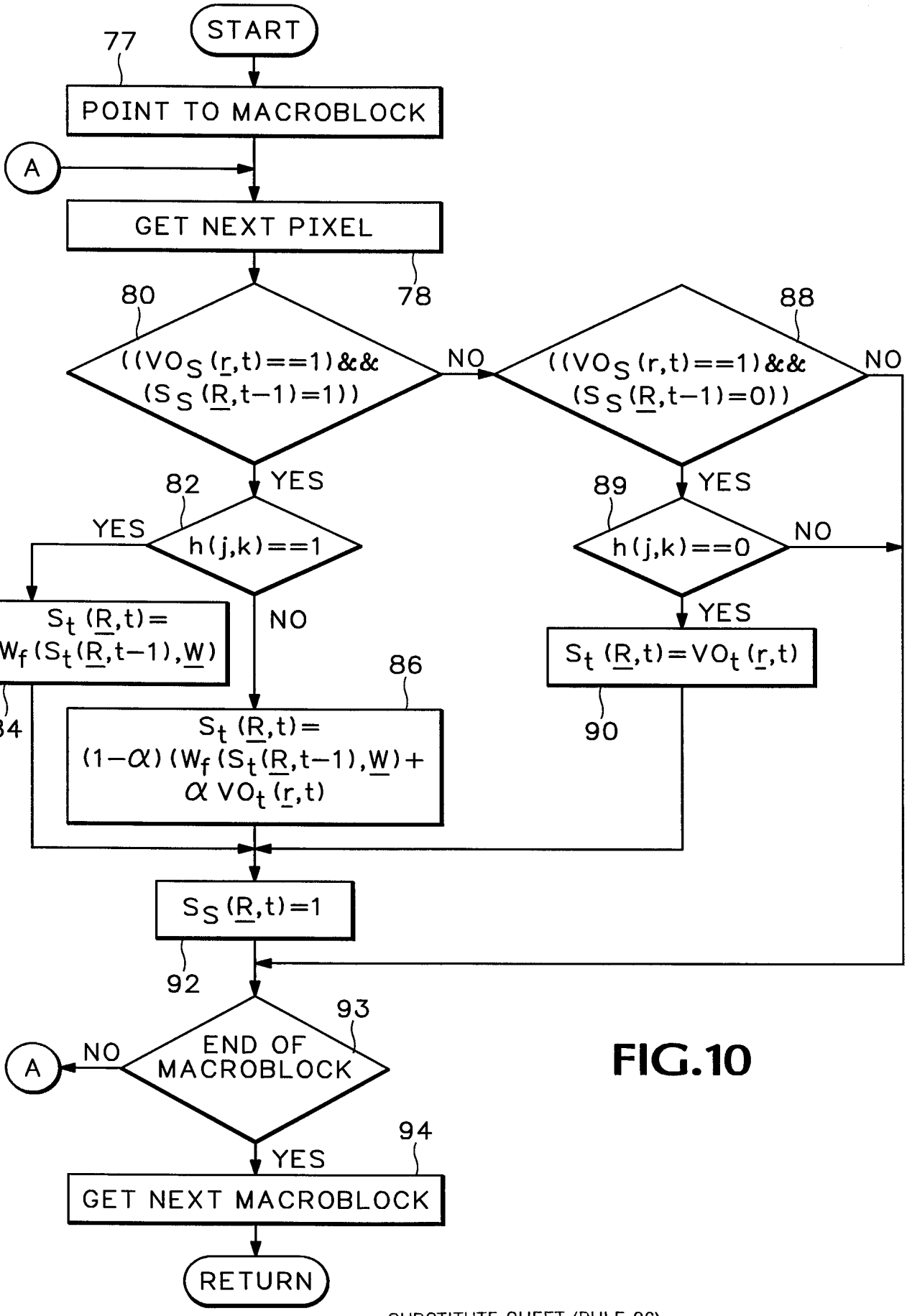

START
77
POINT TO MACROBLOCK
A
GET NEXT PIXEL
78
80
((VOS(r,t)==1)&&
(SS(R,t−1)=1))
NO
88
((VOS(r,t)==1)&&
(SS(R,t−1)=0))
NO
YES
82
h(j,k)==1
YES
NO
89
YES
h(j,k)==0
NO
YES
St(R,t)=
(Wf(St(R,t−1),W)
St(R,t)=VOt(r,t)
84
86
90
St(R,t)=
(1−α)(Wf(St(R,t−1),W)+
α VOt(r,t)
SS(R,t)=1
92
93
A
NO
END OF
MACROBLOCK
94
YES
GET NEXT MACROBLOCK
RETURN

FIG.10

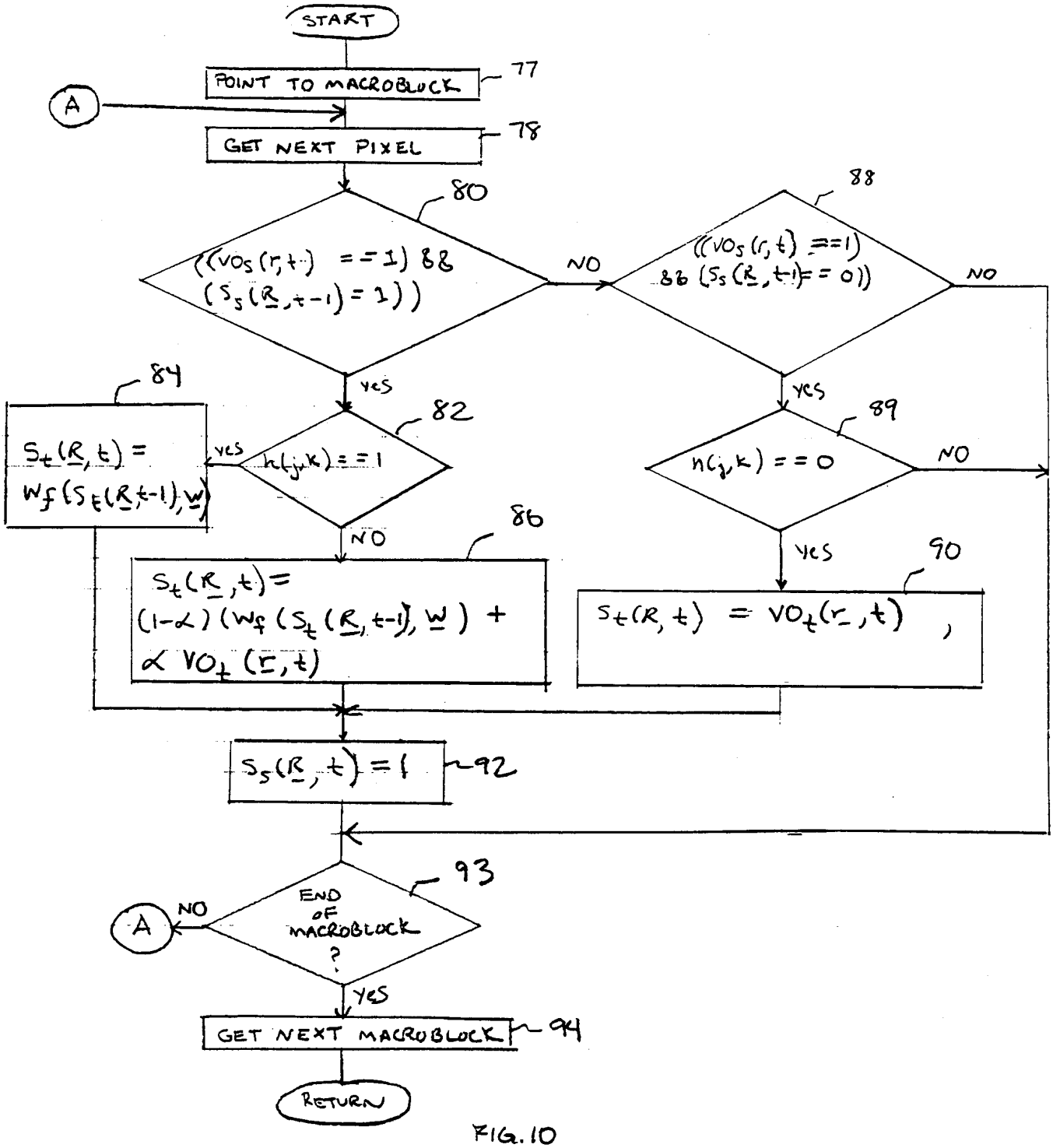

START
POINT TO MACROBLOCK
77
A
GET NEXT PIXEL
78
80
((VOs(r,t) == 1) && (Ss(R,t-1) = 1))
NO
88
((VOs(r,t) == 1) && (Ss(R,t-1) = 0))
NO
YES
YES
84
St(R,t) = Wf(St(R,t-1), W)
YES
82
h(j,k) == 1
89
n(j,k) == 0
NO
NO
86
St(R,t) = (1-α)(Wf(St(R,t-1), W) + α VOt(r,t)
YES
90
St(R,t) = VOt(r,t)
Ss(R,t) = 1
92
93
END OF MACROBLOCK ?
NO
A
YES
GET NEXT MACROBLOCK
94
RETURN

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 98/00732

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04N7/26 H04N7/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04N G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 96 15508 A (SARNOFF DAVID RES CENTER) 23 May 1996 see page 2, line 6 - line 36	1-7, 14-19
A	see page 6, line 11 - page 8, line 9 see page 10, line 31 - page 11, line 35 see page 18, line 29 - page 25, line 13 ---	8-13,20, 21
X	IRANI M ET AL: "VIDEO COMPRESSION USING MOSAIC REPRESENTATIONS" SIGNAL PROCESSING. IMAGE COMMUNICATION, vol. 7, no. 4/06, 1 November 1995, pages 529-552, XP000538027	1-6, 14-19
Y	see page 534, paragraph 2.2 - page 541, paragraph 4.3; figure 6	7
A	--- -/--	8-13,20, 21

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 July 1998	20/08/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Foglia, P

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 98/00732

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
E	WO 98 29834 A (SHARP KK) 9 July 1998 see the whole document	1-21
Y	DUFAUX ET AL: "Background Mosaicking for low bit rate Video Coding" PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING, vol. I/III, 16 September 1996, pages 673-676, XP002073401 lausanne, ch	1-7, 14-19
A	see the whole document	8-13,20, 21
Y	LEE M -C ET AL: "A LAYERED VIDEO OBJECT CODING SYSTEM USING SPRITE AND AFFINE MOTIONMODEL" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, vol. 7, no. 1, February 1997, pages 130-144, XP000678886 see page 133, paragraph III.C - page 134	1-7, 14-19
A	see page 137, paragraph IV - page 140, paragraph V	8-13,20, 21
A	TANNENBAUM ET AL: "Evaluation of a Mosaic Based Approach to Video Compression" 1996 IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING CONFERENCE PROCEEDINGS, 7 May 1996, pages 1213-1215, XP002073402 atlanta, ga, usa see the whole document	1-21

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 98/00732

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9615508 A	23-05-1996	US 5649032 A	15-07-1997
		EP 0792494 A	03-09-1997
WO 9829834 A	09-07-1998	NONE	